APPENDIX B

RISK AND RELIABILITY ANALYSIS/ECONOMICS

U.S. ARMY CORPS
OF ENGINEERS

MAJOR REHABILITATION REPORT:
MAIN REPORT and ENVIRONMENTAL ASSESSMENT
Appendix B – Risk and Reliability/Economics

BOLIVAR DAM

SANDY CREEK OF THE TUSCARAWAS RIVER, OHIO

PREPARED BY: USACE, HUNTINGTON DISTRICT

DRAFT REPORT – JULY 2008

DAM SAFETY PROGRAM
MAJOR REHABILITATION REPORT AND ENVIRONMENTAL ASSESSMENT

APPENDIX B
RISK AND RELIABILITY/ECONOMICS

BOLIVAR, OH
SANDY CREEK

Addenda

1. Flood damages
2. Lost flood protection during repairs
3. Recreation benefits foregone during repairs
4. Bolivar event trees
5. Incremental benefits
6. Other Considerations
7. Road Damages

1. Introduction

In accordance with ER 1130-2-500, the Huntington District has completed a Major Rehabilitation Report for Bolivar Dam, located in the Muskingum River Basin in Ohio. Recent flooding and periodic inspections of the dam have revealed significant dam safety concerns. These concerns stem from the fact that the integrity of the dam has deteriorated over time. The extent of the deterioration became evident during a high water event in 2005, when numerous seepage areas were observed in the downstream area of the dam. The extent of the problems led the national dam safety team to examine the project and classify it as DSAC (Dam Safety Action Class) II according to the USACE Dam Safety Action Classification System.

The DSAC II class includes dams with confirmed (unsafe) and unconfirmed (potentially unsafe) dam safety issues, and where failure could begin during normal operations or be initiated as the consequence of a high water event. The likelihood of unsatisfactory performance from one of these occurrences is too high to assure public safety. DSAC II dams are classified as urgent, unsafe or potentially unsafe, and are second in terms of criticality. The most critical classification is DSAC I, and dams in this class are designated as urgent and compelling with respect to being unsafe.

Following its DSAC II classification detailed studies and observation during subsequent flood events have confirmed the seriousness of the dam safety concerns at the dam and indicate that extensive repairs may be required. It is the purpose of this study to determine if rehabilitation is economically feasible.

1.1 Study Purpose

The purpose of this economic analysis is to quantify and qualify the economic impacts of Bolivar Dam's current operating condition, evaluate rehabilitation plans that address the problems, opportunities and the timing thereof at the dam and determine the economic feasibility of implementing said rehabilitation plans. The objective is to identify the most efficient plan for correcting the seepage problems. This evaluation will also describe the expected losses to property, loss of project benefits, potential loss of life to the population at risk and other losses that would occur in the event of a failure of the Bolivar Dam.

1.2 Project Description

Bolivar Dam is one in a system of 14 original Muskingum River Basin projects constructed by the Corps between 1934 and 1938 under the authority of the Public Works Administration. Presently, there are 16 dams located in the system including the original 14 and two others – North Branch Dam and Dillon Dam, built in 1972 and 1961, respectively. Bolivar Dam itself was completed in 1938. The system is operated in cooperation with the Muskingum Watershed Conservancy District of Ohio to provide flood control, recreation, and conservation of fish and wildlife throughout the watershed.

Additionally, Bolivar is one of 4 dams which make up the Dover group of flood control projects and is located approximately ten miles upstream of Dover Dam.

The project is a dry dam located on the Sandy Creek of the Tuscarawas River, 183.4 miles above the mouth of the Muskingum River, located in Stark and Tuscarawas Counties of Ohio. The Dam has an impervious core with a cut-off trench and is flanked by pervious zones. The embankment has a maximum height of 87 feet, a crest length of 6,300 feet, and a crest width of 25 feet. Constructed primarily for flood control, the maximum flood control pool level of elevation 962.00 feet (also the crest elevation of the spillway) would encompass 6,500 surface acres. There are two levees, Magnolia Levee and East Sparta Levee, within the Bolivar Dam reservoir.

Since Bolivar Dam is a dry dam, it does not have a permanent pool or lake. Only during times of excessive rain when the project is operated to prevent downstream flooding does the dam retain water.

Figure 1 provides a map of the Muskingum River Basin, showing Bolivar in relation to the other dams in the system. An aerial photo of Bolivar Dam is provided as Figure 2.

Figure 1 – Map of the Muskingum River Basin Reservoir System

Figure 2: Bolivar Dam Photo

1.3 Historical Project Benefits

The authorized project purposes of Bolivar Dam are flood damage reduction and recreation, from which project benefits are derived. Annual project flood control benefits for flood damage reduction are calculated by averaging the historic annual benefits. Recreation benefits for Bolivar Dam were calculated using the Unit Day Value (UDV) estimation method. Both of these categories are discussed in depth below.

1.3.1 Flood Damage Reduction

Bolivar Dam has prevented significant flooding over the life of the project. There have been no occurrences of water entering the spillway following completion of the project in 1938. As previously mentioned, Bolivar Dam is one of 16 flood control dams within the Muskingum Basin System. Benefits within the Muskingum River System are attributed to the entire system, rather than to individual projects. Previous studies have been performed to determine an appropriate breakdown of the total benefits of the Muskingum Basin System on a project by project basis that would be applicable to long term averaging. These studies involved a detailed analysis of several selected Muskingum River floods in which contribution by individual projects at each evaluation center was computed. Bolivar is credited with 6.7% of the total benefits attributed to the Muskingum Basin System as reported in *Piedmont Lake, Dam Safety Assurance Evaluation Report*, dated April 1996. The percentage breakdown per project in the Muskingum Basin System is presented in Table 1. This percentage was applied to historical damages prevented to derive a benefit distribution attributable to Bolivar.

Table 1 – Percentage Breakdown of Muskingum River System Benefits

Project	Percent of Total Benefits
Atwood	1.9
Beach City	10.3
Bolivar	6.7
Charles Mill	3.7
Clendening	1.7
Dover	15.2
Leesville	1.3
Mohawk	25.0
Mohicanville	6.4
Piedmont	1.3
Pleasant Hill	4.9
Senecaville	2.7
Tappan	2.1
Wills Creek	17.0

The historic damages prevented by both the Muskingum Basin System and Bolivar Dam are presented in Addendum 2 to this Appendix. Historic damages prevented are shown both at the price level of each indicated year and in FY 2008 dollars. The yearly damages prevented are averaged to arrive at a number that represents the average of the annual benefits provided by the project. This number is $7,104,589 in FY 2008 levels. The total flood damages prevented by the project in FY 2008 price levels[1] for years 1937-2007 are approximately $511,549,860. These are based on aggregated stage-damage and benefit data developed by the original study for the system. The data has been adjusted in order to make appropriate estimates where current stream gage stations are located and are indexed to current price levels each year. Observed peak stages during each flood event that are above zero damage at the gages are compared with estimates of what the natural stages would have been without the constructed project in order to estimate flood damage reduction benefits for the year.

1.3.2 Recreation Benefits

Recreation opportunities at the Bolivar Dam consist of day use facilities set up primarily for picnicking and fishing, limited hunting and trapping, and an equestrian trail. While there are no marked hiking trails on the grounds, hiking is permitted on the equestrian trails and in the surrounding woodland. Annual visitation data for the project was obtained from the Operations and Maintenance Business Information Link (OMBIL)

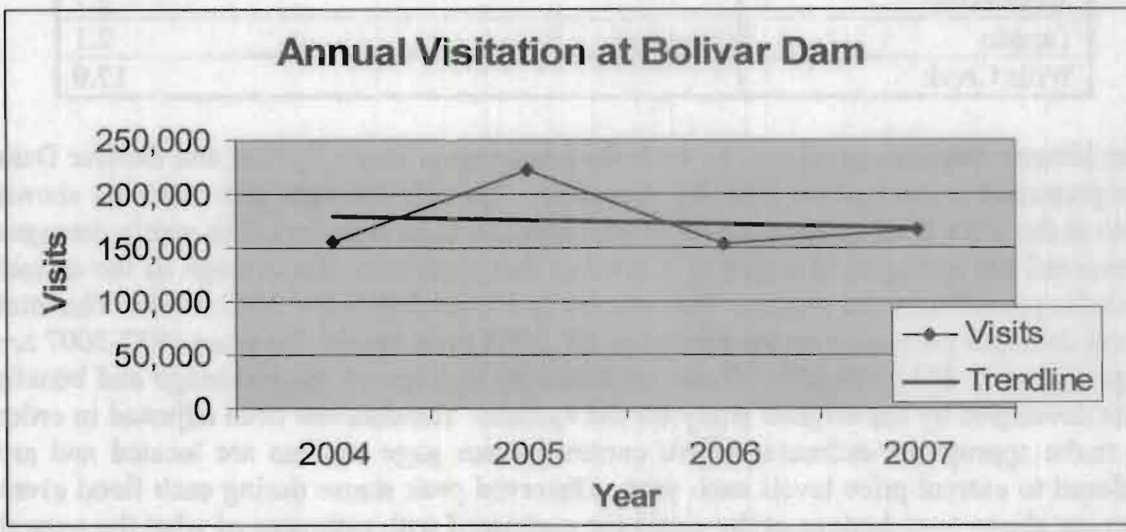
[1] With the exception of the historical damages prevented, all other dollar figures presented in Appendix B are in 01-Oct-2007 (FY08) dollars.

system for the past 4 years[2], from 2004 to date. Average annual visitation at Bolivar Dam totals 174,336 visits and is presented in Table 2. The historic annual visitation and the resulting trend line are presented graphically in Figure 3.

Table 2 - Recent Historic Visitation

	Fiscal Year	Visitor Hours	Visits
	2004	469,249	156,419
	2005	664,672	221,559
	2006	459,742	153,246
	2007	498,362	166,120
Average		523,006	174,336

Figure 3 - Recent Historic Visitation



The Unit Day Value (UDV) method established in ER 1105-2-100, Appendix E, Section VII was employed as a proxy for willingness to pay in order to estimate the current recreation benefits of Bolivar Dam. The UDV method employs a set of five criteria (recreation experience, availability of opportunity, carrying capacity, accessibility and environment) upon which the project site is evaluated and assigned points. The point total is then multiplied by the associated UDV in order to convert the assigned points to a dollar value representing estimated recreation benefits. The UDVs are established in Economic Guidance Memorandum, 08-02, Unit Day Values for Recreation, Fiscal Year 2008 (EGM-08-02) dated 19 October 2007. The point assignments for each recreation component were developed by the project design team's economist and environmental planner and are presented in Addendum 3 to this Appendix.

[2] The OMBIL system was unable to provide data prior to 2004.

The average of the annual visitation to Bolivar Dam for the preceding four years is 174,336, as previously stated. With 29 estimated general recreation points, the appropriate UDV is $5.04, yielding estimated total annual recreation benefits of $877,956 ($5.04 x 174,336 annual visits = $877,956).

1.3.3 Total Equivalent Average Annual Project Benefits

Total quantified annual Bolivar Dam benefits are $7,982,545 as shown in Table 3.

Table 3 - Summary of Equivalent Average Annual Benefits
(FY08 x1000)

Benefit	Annual Benefits
Flood Control	$7,104,589
Recreation	$877,956
Total	**$7,982,545**

1.4 Major Rehabilitation Evaluation Study Methodology

Existing guidance provides two different programs for correction of dam safety issues at Corps projects. The Dam Safety Assurance (DSA) program covers dams with hydrologic, hydraulic, and/or seismic-related problems. Bolivar Dam falls under the Dam Safety program, which addresses projects where dam safety concerns stem from seepage-related problems. The Dam Safety program requires the preparation of a Major Rehabilitation Report (MRR).

The emphasis in an MRR is determining the economic feasibility of rehabilitation while the emphasis in a DSA is in determining the population at risk. Efforts are underway to combine the procedures to produce "Dam Safety Deficiency Modification Reports" for the evaluation of all dam reliability problems but this has not yet been completed. The procedures will be presented in ER 1110-2-1156. To a certain extent, this analysis attempted to address the major issues and areas presented in the draft ER. A list of guidance related to the evaluation of dam reliability problems is provided in Table 4.

Table 4 – Reference Documents

Regulation	Title
ER 1110-2-1156	Safety of Dams – Policy and Procedures (update of EC 1110-2-6061)
ER 1110-2-6064	Interim Risk Reduction Measures for Dam Safety
ER 1110-2-6061	Safety of Dams – Policy and Procedures – 2 types of problems
ER 1130-2-500	Project Operations, Partners and Support (Work Management Guidance and Procedures) – RER procedure
ER 1110-2-1155	Dam Safety Assurance Program

2. Base Condition

The base condition is the current condition of the project components and their expected condition if status quo practices of operation, maintenance and repair are continued. This condition is also referred to as the baseline, without project, existing condition, "fix-as-fails," or the "do nothing" alternative. It is the condition to which all other evaluated alternatives are compared in order to determine their effectiveness as an investment in the project.

The Base Condition represents the minimal capital investment alternative in terms of doing preventative maintenance on the dam components. This method does not prevent failures, but repairs components when they fail. If a project component fails under the base condition, it is assumed that emergency repairs will be made to the feature.

As described in the Main Report Section 4.4, the District has determined that it is in the public's interest to pursue implementation of an interim operating pool and regulation plan at elevation 949.0. The interim plan would require floodwaters to be released earlier than the previous plan to prevent pool levels from exceeding unsafe elevations that would threaten the integrity of the dam. For the purposes of the economic analysis, the base condition was defined as a fully functioning project to fully account for the negative economic consequences (i.e. lost flood protection benefits), or disbenefits in the event of unsatisfactory performance, which for the purposes of this analysis is defined as either catastrophic failure or significant seepage.

A breach of the Bolivar Dam would cause significant damage to residential, commercial, industrial and agricultural properties downstream of the dam along Sandy Creek, Tuscarawas and Muskingum Rivers and several of their tributaries including the Licking, Stillwater, Little Stillwater, Muskingum, Walhonding Rivers and Wills Creek.

2.1 Baseline Condition Considerations

2.1.1 Effects of Bolivar Dam on Dover Dam

As previously stated, Bolivar Dam is one of 16 dams in the Muskingum River Basin that operate as a system to reduce flood damage. Bolivar is located directly upstream of Dover Dam on Sandy Creek, a tributary of the Tuscarawas River. Dover Dam is currently classified as a DSAC II dam. A Dam Safety Assurance (DSA) study for the Dover Dam was completed in July 2007. The DSA study recommends raising and anchoring the dam to allow for it to safely pass the 100% of the Probable Maximum Flood (PMF). The DSA report has been approved and construction is scheduled to begin in 2012.

The Dover pool stretches upstream to the toe of Bolivar Dam. Because of the close relationship between the two projects it is necessary to discuss the effects on Dover Dam in the event of a failure of Bolivar Dam.

2.1.1.1 Risk Based Model Considerations

For the purposes of the risk based model for this MRR it is assumed that for the first seven years of the analysis that Dover Dam would fail should the water elevation behind the dam reach 907. Therefore, Dover Dam would fail in the event of a Bolivar Dam failure, were that failure to cause the water elevation behind Dover Dam to exceed 907. After the first seven years it is assumed that Dover Dam has been fully repaired and able to withstand a Bolivar Dam failure.

2.1.1.2 Interim Operating Pool Considerations

To address public safety during high flow events the District has set a target Interim Operating Pool (IOP) for Dover Dam. This target elevation was determined through analysis of current engineering criteria and data. Initially the IOP was set at elevation 907, nine feet below the spillway crest of 916. In March of 2008 bar anchors were installed at Dover Dam as part of the Interim Risk Reduction plan. The addition of the bar anchors enabled the District to increase the IOP from elevation 907 to elevation 910[3].

A full discussion of the types of failure, the probabilities of such occurrences and the economic consequences of each is presented in the next two subsections.

[3] The bar anchors at Dover Dam were install subsequent to the conclusion of the Risk Based modeling effort for the Bolivar project. The model assumes that Dover Dam would fail at the original IOP level of 907.

2.1.2 Separable Components

Two sections, or components, of the project have been identified as areas of concern: the main embankment and left abutment, as listed in Table 5. The existing conditions of these two components were evaluated in detail. For complete information on the condition and failure modes of these components reference Appendices H and I of this report.

Table 5 – Separable Components

Component	Description
1	Main Embankment
2	Left Abutment

2.1.3 Pool Elevations Identified for Evaluation

As previously stated, the Bolivar Dam becomes increasingly hazardous as the elevation of the pool behind the dam rises. Based upon this observation the project delivery team's geotechnical members identified a series of pool elevations for evaluation. The various pool elevations are considered to be triggering mechanisms for unsatisfactory performance. These pool elevations and their corresponding probabilities of occurrence are listed in Table 6.

Table 6 – Pool Elevations and Probability of Occurrence

Pool Elevation	Probability of Occurrence
924	99.9%
929	50.0%
936	28.6%
949	1.6%
952	1.1%
962	0.5%
964	0.3%

2.1.4 Probability of Unsatisfactory Performance at Specified Pool Elevations

The probabilities of unsatisfactory performance for each component and for each pool elevation were also provided by the geotechnical team members. The higher the pool elevation, the greater the likelihood that the project components will perform in an unsatisfactory manner, as shown in Table 7.

Table 7 – Probabilities of Unsatisfactory Performance at Different Pool Elevations

Pool Elevation	Main Embankment	Left Abutment
924	0.00%	0.00%
929	0.00%	0.00%
936	0.77%	0.01%
949[4]	96.66%	2.51%
952	97.19%	2.64%
962	98.00%	6.60%
964	99.54%	7.50%

2.1.5 Types of Unsatisfactory Performance

Two types of unsatisfactory performance were identified by the team for Bolivar Dam: 1) catastrophic failure; and 2) significant seepage (consequences without failure). The likelihood of a catastrophic failure and significant seepage increase as the elevation of the pool increases, as shown in Table 8.

Table 8 – Probabilities of Different Types of Unsatisfactory Performance

	Main Embankment		Left Abutment	
Pool Elevation	Catastrophic Failure	Significant Seepage	Catastrophic Failure	Significant Seepage
924[5]	0%	1%	0%	1%
929	1%	99%	0%	100%
936	5%	95%	1%	99%
949	10%	90%	1%	99%
952	30%	70%	1%	99%
962	60%	40%	6%	94%
964	60%	40%	10%	90%

2.1.6 Event Tree

The paths of possible future events related to the reliability of Bolivar are partially depicted in the event tree shown in Figure 4. The complete event trees developed for this study are provided in Addendum 4 to this Appendix. The event tree shows the possible

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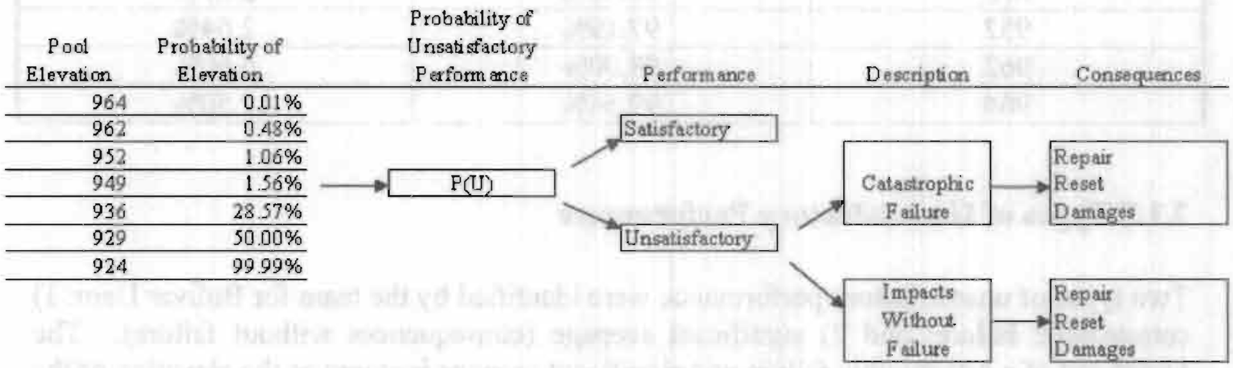
[4] The probabilities of unsatisfactory performance increase significantly at the pool elevation 949. At lower pool levels the through seepage potential failure mode is not an issue. However, when the pool reaches 949 through seepage becomes an issue and results in higher Pr(u) values. A full explanation is available in the geotechnical embankment appendix.

[5] The probabilities must sum to 100%. At 924 a third possibility was added of an extremely minor failure with a 99% probability of occurrence and zero adverse consequences. The third possibility is not shown above.

pool elevations, the probabilities of their occurrences, the probabilities of unsatisfactory performance and the consequences of each type of unsatisfactory performance.

Figure 4: Event Tree



2.2 Consequences of Unsatisfactory Performance

The economic consequences of unsatisfactory performance include the cost of repairing the project, downstream flood damages, the loss of flood protection while the project is under repair, the loss of recreation benefits while the project is under repair, and road damages. Another consideration under consequences of unsatisfactory performance is Population at Risk (PaR) and Loss of Life (LoL). A complete discussion of these concerns can be found in Addendum 4 to this Appendix.

2.2.1 Repair Costs

It is assumed that repairs will be made if the project fails in some manner. A catastrophic failure requires significant repairs regardless of the pool elevation at the time of failure. For events that do not result in failure, but which do cause impacts to the dam, the repairs are generally related to the pool elevation at the time of the event, as shown in Table 9. Repair costs were developed by the cost engineering team members, in conjunction with geotechnical and hydraulic team members.

Table 9 – Repair Costs by Pool Elevation
(x1000)

	Main Dam		Left Abutment	
Pool Elevation	**Catastrophic Failure [6]**	**Significant Seepage**	**Catastrophic Failure**	**Significant Seepage**
924	$33,187	-	$33,187	-
929	$33,187	$350	$33,187	$350
936	$33,187	$350	$33,187	$350
949	$33,187	$1,800	$33,187	$1,800
952	$33,187	$1,800	$33,187	$1,800
962	$33,187	$6,500	$33,187	$6,500
964	$33,187	$6,500	$33,187	$6,500
982	$33,187	$12,500	$33,187	$12,500

2.2.2 Flood Damages

Flood damages were estimated based on H&H water surface profiles and structure inventory data as input to the Hydraulic Engineering Center Flood Damage Analysis (HEC-FDA) computer model. The data and methodology are provided in Addendum 1 to this Appendix. Flood damages vary by pool elevation and type of unsatisfactory performance, as shown in Table 10.

Table 10 – Flood Damages by Pool Elevation
(x1000)

	Main Embankment		Left Abutment	
Pool Elevation	**Catastrophic Failure**	**Significant Seepage**	**Catastrophic Failure**	**Significant Seepage**
906.0	$26,424	$633	$26,424	$633
929.0	$36,433	$1,852	$36,433	$1,852
936.0	$63,758	$6,198	$63,758	$6,198
949.0	$70,696	$6,715	$70,696	$6,715
952.0	$347,367	$6,715	$347,367	$6,715
962.0	$371,963	$6,715	$371,963	$6,715
964.0	$2,019,006	$6,715	$2,019,006	$6,715

2.2.3 Lost Flood Protection During Repairs

In the case of unsatisfactory performance the project would not be able to provide flood protection for downstream communities while repairs to the project were made. The

[6] One half of amount ($16,594) spent in each of two year construction period.

procedure and computation of the lost flood protection during repairs used in this analysis are documented in Addendum 2 to this Appendix. The values are listed in Table 11.

Table 11 – Lost Flood Protection During Repairs (x1000)

	Main Embankment		Left Abutment	
Pool Elevation	Catastrophic Failure	Significant Seepage	Catastrophic Failure	Significant Seepage
924	$5,560	$2,780	$5,560	$2,780
929	$7,105	$3,552	$7,105	$3,552
936	$7,105	$3,552	$7,105	$3,552
949	$7,105	$3,552	$7,105	$3,552
952	$7,105	$3,552	$7,105	$3,552
962	$7,105	$3,552	$7,105	$3,552
964	$7,105	$3,552	$7,105	$3,552
982	$7,108	$3,554	$7,108	$3,554

2.2.4 Lost Recreation Benefits During Repairs

The area around the project is used for recreational activities that would be temporarily disrupted following some type of unsatisfactory performance. The recreational benefits forgone were computed based on the Unit Day Value (UDV) methodology established in ER 1105-2-100, Appendix E, Section VII. As previously discussed, precise methodology for this practice is outlined in Economic Guidance Memorandum, 08-02, Unit Day Values for Recreation, Fiscal Year 2008. The procedure and computation of recreation benefits foregone at the project during repairs are documented in Addendum 3 to this Appendix. The values are listed in Table 12.

Table 12 – Recreation Benefits Foregone During Repairs (x1000)

	Main Embankment		Left Abutment	
Pool Elevation	Catastrophic Failure	Significant Seepage	Catastrophic Failure	Significant Seepage
924	$873	$437	$873	$437
929	$878	$439	$878	$439
936	$878	$439	$878	$439
949	$878	$878	$878	$878
952	$878	$878	$878	$878
962	$878	$878	$878	$878
964	$878	$878	$878	$878
982	$878	$878	$878	$878

2.2.5 Road Damages

Road damages were estimated based on shape files of the road networks within the basin obtained from the Tuscarawas County GIS website. This was imported into ARC GIS and overlain on inundation mapping of a PMF dam failure of Bolivar dam, which defines the economic study area. Complete data and methodology are provided in Addendum 7 to this Appendix. Road damages vary by pool elevation and are shown for the Base Condition and With Rehab Condition in Tables 13 and 14, respectively.

Table 13 – Base Condition: Road Damages by Pool Elevation (x1000)

Pool Elevation	Miles of Roads	Damages
906	11.73	$17,588
929	13.69	$20,528
936	15.93	$23,888
949	17.57	$26,355
952	166.29	$249,428
962	176.02	$264,023
964	350.00	$525,000

Table 14 – With Rehab Condition: Road Damages by Pool Elevation (x1000)

Pool Elevation	Miles of Roads	Damages
906	0.28	$422
929	0.70	$1,043
936	1.55	$2,322
949	1.67	$2,504
952	166.29	$249,428
962	176.02	$264,023
964	350.00	$525,000

3. Alternatives Development

3.1 Initial Array of Alternatives

Current Corps guidance requires consideration of four basic project alternatives in reliability studies. These alternatives are listed in Table 15 and discussed below. The second two alternatives – scheduled rehabilitation and immediate rehabilitation – provide the framework by which the team developed the final array of alternatives.

Table 15 – Initial Set of With Rehab Condition Project Alternatives

1. Advanced maintenance
2. Scheduled repair
3. Scheduled rehabilitation
4. Immediate rehabilitation

3.1.1 Advanced Maintenance Strategy

Advance maintenance strategies would consist of expenditures in excess of routing O&M that reduces the likelihood of some emergency repairs and temporary service losses, or the rate of service degradation. The existing O&M budget could be increased to provide funds for advanced maintenance toward the problem or for scheduled repairs. This would essentially entail attempting to correct the problem over time as the potentially increased O&M budget would permit.

As previously stated, the problems with the dam are linked to pool elevations which can only partially be remediated with advanced maintenance. This alternative does not address the underlying reliability problems in an effective and efficient manner. This alternative was also considered as a possible interim risk reduction measure but was not found to be effective. This alternative was excluded from further study.

3.1.2 Scheduled Repair Strategy

A scheduled repair strategy would assess the components of the project in terms of the service disruption probabilities and consequences to the reliability of the structure. Based on this assessment, the district would stockpile replacement parts and make other preparations on this assessment to reduce the time of expected project service disruption. Like the advanced maintenance alternative this plan was also eliminated from further study due to its failure to adequately address the underlying reliability problems at the dam in an effective an efficient manner.

3.1.3 Scheduled Rehabilitation

The scheduled rehabilitation strategy requires that the optimum rehabilitation timing be identified based on service disruption rates, service degradation and their economic cost. This alternative was carried forward for further evaluation and found inferior to immediate rehabilitation based on maximization of net benefits.

3.1.4 Immediate Rehabilitation

Immediate rehabilitation is rehabilitation at the earliest possible date. This alternative was evaluated and proved to be the most economically feasible alternative.

A brief summary of initial screening rationale for each alternative is presented in Table 16.

Table 16 – Initial Screening of With Rehab Condition Project Alternatives

Criteria[7]	Advanced Maintenance	Scheduled Repair	Immediate Rehabilitation	Scheduled Rehabilitation
Completeness	No	No	Yes	Yes
Effectiveness	No	No	Yes	Yes
Efficiency	No	No	TBD	TBD
Acceptability	No	No	Yes	Yes
1) Implementability	No	No	Yes	Yes
2) Satisfaction	No	No	Yes	Yes

3.2 Final Array of Alternatives

As previously stated, engineering studies and field observation during high flow events identified two separate project components with dam safety concerns. As separable components, rehabilitation of both the Main Embankment and the Left Abutment are required to be justified independently of each other. Therefore separate alternatives were developed to address each component.

The presence of two separate project components (Main Embankment and Left Abutment) led to the formulation of six alternatives for detailed consideration. Separate alternatives were developed to address each of the two components. The final array of alternatives is discussed in the following subsections.

[7] Source for Criteria: "Planning Manual", November 1996, IWR Report 96-R-21.

3.2.1 Immediate Rehabilitation Alternatives

Immediate rehabilitation is the rehabilitation of the project in the shortest amount of time possible. Typically even the quickest fix requires several years to design, advertize for construction, and perform the actual construction. The project is expected to be budgeted in FY 2010 with two years for pre-construction activities followed by four years of construction. Therefore the completion date for immediate rehabilitation is assumed to be the end of 2015.

3.2.1.1 Immediate Rehabilitation of Main Embankment and Left Abutment

One variation of immediate rehabilitation would be the rehabilitation of both components of the project that are considered unreliable. Both could be completed by 2015 if funding was available.

3.2.1.2 Immediate Rehabilitation of Main Embankment Only

A second variation of the immediate rehabilitation alternative is the rehabilitation of only the main embankment of the dam. This is the largest part of the rehabilitation effort with an early completion date of 2015.

3.2.1.3 Immediate Rehabilitation of Left Abutment Only

The third variation would be the rehabilitation of the left abutment only. The early completion date for this plan is 2013.

3.2.2 Scheduled Rehabilitation Alternatives

Scheduled rehabilitation is the deferral of the initiation of the rehabilitation effort into the future. The timing is keyed to the reliability of the project and the consequences of unsatisfactory performance. The analysis may indicate that the risks and consequences are not significant enough at the current time to warrant rehabilitation work, but that future rehabilitation may be warranted if the risks or consequences increase over time. For the purposes of this analysis it was assumed that the date for scheduled rehabilitation would be 10 years beyond the date of the immediate rehabilitation effort. Shorter time periods are generally within the time variation of a construction schedule of this magnitude of work while dates further in the future are interesting but of limited use in that an updated analysis would likely be required prior to funding such work. The early completion date for scheduled rehabilitation is 2025.

3.2.2.1 Scheduled Rehabilitation of Main Embankment and Left Abutment

The early completion date for scheduled rehabilitation of both components of the project is 2025.

3.2.2.2 Scheduled Rehabilitation of Main Embankment Only

The early completion date for scheduled rehabilitation of the main embankment is 2025. If the left abutment was justified for immediate rehabilitation, then both components could be included in an approved plan with an extended completion date somewhere between 2013 and 2025.

3.2.2.3 Scheduled Rehabilitation of Left Abutment Only

The early completion date for scheduled rehabilitation of the left abutment is 2022. If the main embankment was justified for immediate rehabilitation, then both components could be included in an approved plan with an extended completion date somewhere between 2015 and 2022.

4. Risk and Reliability Analysis Methodology

The economic feasibility of the alternatives plans was evaluated using risk and reliability analysis. This was accomplished by developing a life cycle simulation model that considered the reliability of the project and the expected consequences of unsatisfactory performance. The core logic of the model is based on the possible sequences of events as shown on the event tree. The model is designed to simulate the performance of the project for a fifty year time period, i.e. it performs life-cycle analysis. Excel software with the @RISK add-on feature was used for the programming. The model was documented and reviewed. Based on the review it was submitted for certification as a regional model but the process for certification was still underway as of July 2008.

4.1 Purpose of Model

The purpose of the model is to calculate the repair costs and reduction in benefits associated with the reliability of the project. The model keeps a running tabulation of repair costs and disbenefits for each of the fifty years in the project life and for each of twenty thousand life-cycle simulation runs. Following completion of the simulation, the disbenefits and repair costs by year are converted to their present value equivalents, summed, and converted to an average annual equivalent value, which is then used in the benefit to cost calculation. The model was designed to perform these operations for the project as a whole and for each of the separable components.

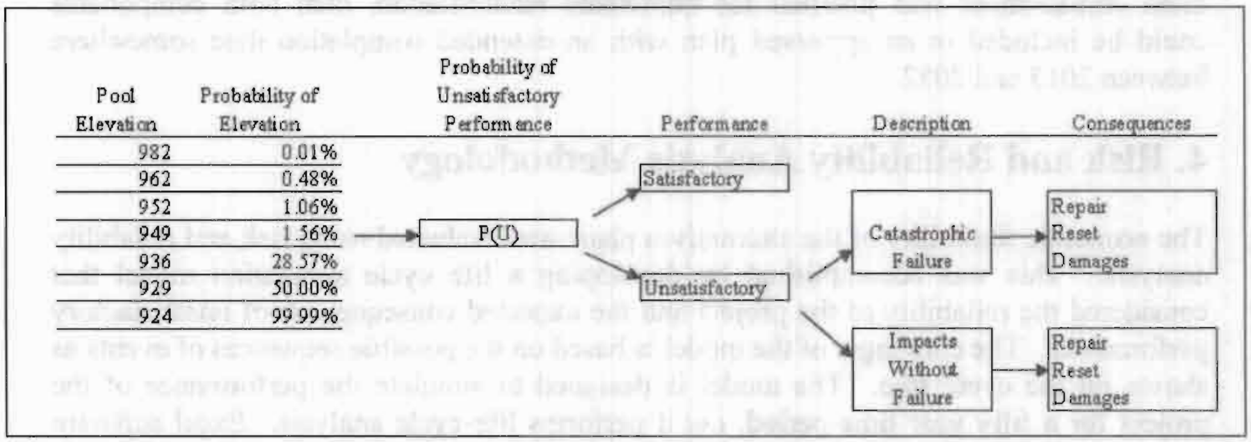
4.2 Model Software

The model is an "Excel" workbook enhanced with the @RISK software developed by the Pallisades Corporation. Excel and @RISK are both commercial-off-the-shelf software applications with wide use by academic, corporate, and government entities. The model includes embedded formulas developed and/or entered into the @RISK enhanced Excel workbook that are sequentially executed as part of the simulation process.

4.3 Model Structure

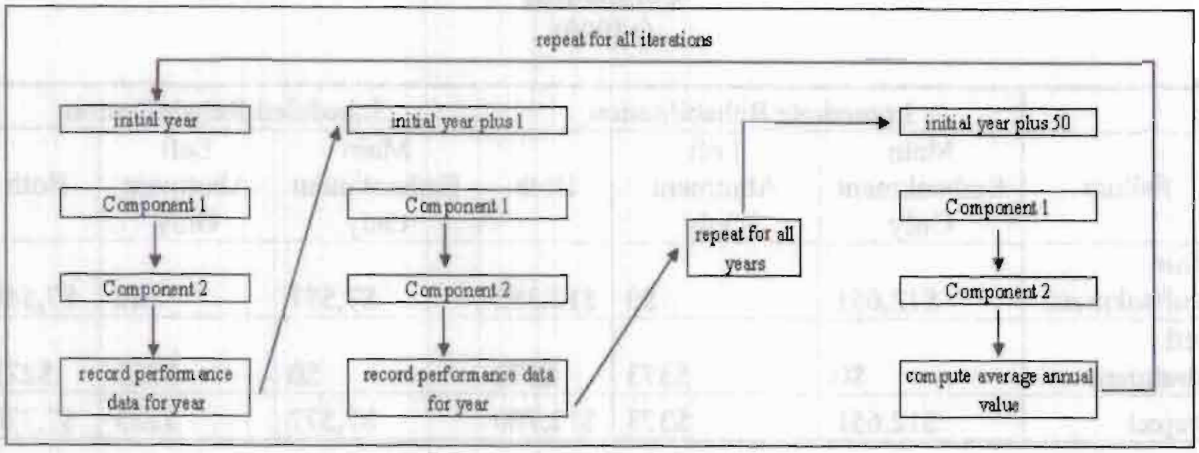
The model is a software encoded version of the event trees. The sample event tree is presented once more as Figure 5; the event trees for the Main Embankment and Left Abutment are identical.

Figure 5: Event Tree



The event tree depicts the possible conditions and sequences of events with regard to the project in any given year. This depiction is the framework for computer code of the model that simulates performance and consequences given probability values. The code is copied fifty times for fifty years in order to perform life cycle analysis. The overall structure of the life cycle model is shown as Figure 6.

Figure 6 – Multiple Iterations of Life Cycle Analysis



The model is run twenty thousand times for the Base Condition with each new life-cycle run being independent of other runs. The outputs for each run are stored in memory until all runs are complete. The model is then run for each of the With Rehab Condition alternatives, which have lower probabilities of unsatisfactory performance since those alternatives would increase the structural integrity and reliability of the project. The outputs for the With Rehab Condition alternatives are duly saved and processed in the same manner as the Base Condition outputs.

5. Project Benefits

As previously stated, the benefits provided by Bolivar Dam are in the areas of flood protection and recreation. Failure of the project to function in a reliable manner could result in the loss of these benefits. In addition, unsatisfactory performance could require the expenditure of money to make repairs to the project. Current Corps guidance requires that it be assumed that all failures will be repaired. Therefore, repair costs are an additional economic consequence of unsatisfactory performance. The avoidance of repair costs, flood damages, and recreation benefits foregone are the benefits of the rehabilitation alternative.

5.1 Disbenefits Associated with the Base Condition

The negative economic consequences of the Base Condition were estimated using the simulation model and inputs discussed previously. The sum of the costs of the negative consequences, including the cost to repair the project, are listed in Table 17. The values are listed by components and for the project as a whole. The project values are less than the sum of the component values because the values were screened to avoid double counting when both components failed within the same general time period. The disbenefits are provided for two scenarios: the first that considers the current time period and the second that starts ten years in the future, which coincides with the scheduled rehabilitation alternative.

Table 17[8] – Base Condition: Sum of Repair Costs and Benefits Foregone By Component (x1000)

	Immediate Rehabilitation			Scheduled Rehabilitation		
Failure	Main Embankment Only	Left Abutment Only	Both	Main Embankment Only	Left Abutment Only	Both
Main Embankment	$12,651	$0	$12,382	$7,577	$0	$7,548
Left Abutment	$0	$373	$373	$0	$223	$223
Project	$12,651	$373	$12,700	$7,577	$223	$7,770

The expected repair costs and disbenefits are shown in absolute and relative terms, in Table 18 for the immediate rehabilitation alterative. The relative values would be the same for the scheduled alternative. The vast majority of the negative consequences associated with the existing project are flood damages.

Table 18 – Base Condition: Repair Costs and Benefits Foregone by Impact Area (x1000)

Repair costs	$794	6.3%
Flood damages	$8,158	64.2%
Lost flood protection	$129	1.0%
Recreation benefits foregone	$2,897	22.8%
Road Damages	$721	5.7
Total	$12,699	100%

5.2 Residual Disbenefits of With Rehab Condition Alternatives

The With Rehab Condition was initially evaluated for the immediate rehabilitation of both the main embankment and left abutment. The results were then used to evaluate the economics of the six alternatives carried forward for detailed study. Immediate rehabilitation makes the project highly reliable, such that the residual negative impacts associated with the alternative are near zero, as shown in Table 19.

[8] AAEV is average annual equivalent value at 4 7/8% over 50 years. This is the same for all figures presented in this section.

Table 19 – With Rehab Condition: Repair Costs and Benefits Foregone by Component

Failure	Immediate Rehabilitation			Scheduled Rehabilitation		
	Main Embankment Only	Left Abutment Only	Both	Main Embankment Only	Left Abutment Only	Both
Main Embankment	$2	$0	$2	$2	$0	$2
Left Abutment	$0	$0	$0	$0	$0	$0
Project	$2	$0	$2	$2	$0	$2

The residual negative impacts by impact area are listed in Table 20 for the immediate rehabilitation of both components alternative. The reliability is high and therefore the impacts are negligible.

Table 20 – With Rehab Condition: Repair Costs and Benefits Foregone by Impact Area

Repair costs	$0	13.8%
Flood damages	$1	45.1%
Lost flood protection	$0	3.2%
Recreation benefits foregone	$0	17.5%
Road damages	0	20.4
Total	$2	100%

5.3 Rehabilitated Project Benefits

The benefits of the With Rehab Condition alternatives are the reduction in expected project repair costs and the quantified value of other negative consequences from those in the Base Condition. Again, this assumes immediate rehabilitation. The results for the six project alternatives are listed in Table 21.

Table 21 – With Rehab Condition: Benefits By Component (x1000)

Failure	Immediate Rehabilitation			Scheduled Rehabilitation		
	Main Embankment Only	Left Abutment Only	Both	Main Embankment Only	Left Abutment Only	Both
Main Embankment	$12,650	$0	$12,380	$7,575	$0	$7,546
Left Abutment	$0	$373	$373	$0	$223	$223
Project	$12,650	$373	$12,699	$7,575	$223	$7,769

The benefits by area of impact are listed in Table 22 for the immediate rehabilitation of both components alternative. The major benefit is the reduction in expected flood damages.

Table 22 – With Rehab Condition: Benefits By Impact Area (x1000)

Repair costs	$794	6.3%
Flood damages	$8,158	64.2%
Lost flood protection	$129	1.0%
Recreation benefits foregone	$2,897	22.8%
Road damages	$721	5.7%
Total	$12,699	100%

6. Project Costs

Project costs are the life-cycle costs necessary to design, construct and maintain the project over a fifty year period (the base year for this study is 2014) following the completion of construction. Project costs are discussed below.

6.1 Implementation Costs

Implementation costs for the rehabilitation alternatives include design costs, construction costs, construction management costs, and all other costs necessary to make the project a functional reality. The costs used to perform the life cycle analysis were developed by Huntington District cost engineers using M-CASES software. The implementation costs for the rehabilitation alternatives are listed in Table 23.

The separable costs are the costs for performing work on both the main embankment and left abutment as part of a single work effort. This is the most efficient plan from a cost standpoint. The stand-alone costs are the costs if each element were constructed separately. It was estimated that the stand-alone cost would be at least 1% higher than the costs of a combine effort. The separable costs were increased one percent to compute the stand-alone costs.

Table 23 – With Rehab Condition: Implementation Costs (x1000)

	Single Construction Effort	Two Construction Efforts
Main Embankment	$117,961	$119,141
Left Abutment	$4,023	$4,063
Project	$121,984	$123,204

6.2 Operation and Maintenance Costs

Operation and maintenance (O&M) costs are the annual cost required to operate and maintain the project. There are no additional O&M costs associated with the preferred project alternative.

6.3 Economic Costs of Alternative Plans

The implementation costs were converted into economic costs using an annualization procedure based on a 50 year economic life cycle, a discount rate of 4 7/8%, a four year construction period and mid-year computation of interest. The computation of the average annual equivalent value of the implementation cost for the immediate rehabilitation alternative is shown in Table 24.

6.3.1 Immediate Rehabilitation

Table 24 – Immediate Rehabilitation of Both Components During Single Construction Effort (FY 08 Price Level, x1000)

		Main	PV	Left	PV	Both	PV
-3.5	1.18	30,496	36,024	-	-	30,496	36,024
-2.5	1.13	30,496	34,350	-	-	30,496	34,350
-1.5	1.07	30,496	32,753	-	-	30,496	32,753
-0.5	1.02	26,473	27,111	4,023	4,120	30,496	31,230
	Cum PV	117,961	130,238	4,023	4,120	121,984	134,357
	AAEV		6,997		221		7,218

The computations of the economic costs of the immediate rehabilitation alternatives are shown in Table 25.

Table 25 – Computation of Average Annual Costs for Immediate Rehabilitation Alternatives (FY 08 Price Level, x1000)

	Single Construction Effort			Two Separate Construction Efforts		
	Main	Left	Both	Main	Left	Both
Implementation	$117,961	$4,023	$121,984	$119,141	$4,063	$123,204
IDC @ 4 7/8%	$12,276	$97	$12,373	$12,399	$98	$12,497
Subtotal	$130,238	$4,120	$134,357	$131,540	$4,161	$135,701
AAEV	$6,997	$221	$7,218	$7,067	$224	$7,290
Additional O&M	$0	$0	$0	$0	$0	$0
Total AAEV	$6,997	$221	$7,218	$7,067	$224	$7,290

7. Project Economic Feasibility

Project economic feasibility is determined by comparing the benefits of the project to the costs. If the benefits exceed the costs, then implementation of the project is economically justified. The alternative with the highest net benefits is designated as the National Economic Development (NED) plan – and is therefore the preferred alternative. The benefit to cost ratio (BCR) is the ratio of benefits to costs. The BCR is not a factor in identifying the NED plan, and is provided only for informational purposes. However, the BCR is often used by the Office of Management and Budget (OMB) to prioritize projects.

7.1 Economic Feasibility of Alternative Plans

A total of six alternatives were carried forward for detailed evaluation. The results are listed by decreasing net benefits in Table 26.

Table 26 – Economic Feasibility of Alternative Plans

Alternative	Average Annual Equivalent Values (x1000) Incremental Benefits	Incremental Costs	Net Benefits	BCR
Immediate Rehabilitation of the Main Embankment and Left Abutment	$12,699	$7,218	$5,409	1.8
Immediate Rehabilitation of the Main Embankment	$12,382	$7,067	$5,315	1.8
Scheduled Rehabilitation of the Main Embankment and Left Abutment	$6,000	$4,347	$1,516	1.4
Scheduled Rehabilitation of the Main Embankment	$5,822	$4,390	$1,431	1.3
Scheduled Rehabilitation of the Left Abutment	$179	$139	$40	1.3
Immediate Rehabilitation of the Left Abutment	$373	$224	$150	1.7

The NED plan, due to its being the alternative with the highest net benefits, is the immediate rehabilitation of the main embankment and left abutment.

7.2 Sensitivity Analysis

A range of economics was calculated by considering the minimum and maximum economic consequences in the twenty thousand iterations for a single life cycle analysis. Two other sensitivities were run as well: 1) the economics using the OMB preferred discount rate of 7%; and 2) removing the effect of a Dover project that may not be complete for seven years after the expected on-line date of Bolivar. The results are based on venture level costs and are summarized in Table 27.

Table 27 – Sensitivity Tests
(x1000)

	Benefits	Costs	Net benefits	BCR
Report economics	$12,699	$7,218	$5,481	1.8
OMB rate of 7%	$12,469	$10,149	$2,321	1.2
Dover dam	$10,689	$7,218	$3,471	1.5
Minimum failure values during life cycle analysis	-	$7,218	$(7,218)	0.0
Maximum failure values during life cycle analysis	$199,095	$7,218	$191,877	27.6

7.2.1 OMB Rate of 7%

OMB requires that all construction projects present their benefit to cost ratios using a discount rate of 7% as part of their annual budgetary submittal. The economics at 7% are lower than the report economics, which were developed using a discount rate of 4 7/8%. The reason is the higher opportunity cost of capital as measured by interest during construction.

7.2.2 Dover Dam

As previously discussed, Dover Dam is located approximately 10 miles downstream of Bolivar Dam and is currently being rehabilitated. The base condition of Bolivar accounts for the fact that Dover Dam's rehabilitation effort may not be completed until seven years after the completion of Bolivar. The Dover Dam sensitivity test is based on lower than base condition potential damages during this time, in the event that Dover Dam has been rehabilitated before the Bolivar rehabilitation comes online.

7.2.3 Minimum Failure Values During Life Cycle Analysis

The @RISK simulation program records the outputs for 5% of the runs with the lowest number of hits in terms of random numbers and probabilities. The results are that no significant breaches occur five percent of the time.

7.2.3 Maximum Failure Values During Life Cycle Analysis

The @RISK simulation program records the outputs for 5% of the runs with the highest number of hits in terms of random numbers and probabilities. The results are a high number of catastrophic failures five percent of the time, as indicated by the high benefits for rehabilitation listed in Table 24.

8. Conclusions

As previously, stated the NED plan is the alternative plan that provides the highest net positive benefits. The NED plan for Bolivar is the immediate rehabilitation of both the main embankment and left abutment of the dam. The economics of the NED plan are shown in Table 28.

Table 28 – Economics of the NED Alternatives (x1000)

Average Annual Equivalent Values				
NED Plan	**Incremental Benefits**	**Incremental Costs**	**Net Benefits**	**BCR**
Immediate Rehabilitation of the Main Embankment and Left Abutment	$12,699	$7,218	$5,481	1.8

Addendum 1: Flood Damages

Flood Damages

Flood Damage Estimation Methodology

Due to the certainty of loss of life from failure to conform to current design standards related to seepage and stability issues during high flow events, Bolivar Dam is currently classified as a high hazard dam. The economic losses that would occur both with and without dam failure include damage resulting from inundation to not only residential and commercial structures but also industrial and public properties and their contents in addition to farms and cropland, which are beyond the scope of this study.

In order to fully determine the extent of economic damage resulting from the selected range of pool elevations it is necessary to simulate the pool occurrences with the Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) program. The HEC-FDA program is used to assist PDT members in using risk analysis methods for flood damage reduction studies as required by Corps guidance in EM 1110-2-1319. (For the purpose of this study it was utilized to assign a dollar amount to the economic losses resulting from the selected range of pool elevations both with and without project failure.) The program incorporates descriptions of uncertainty of key parameters and functions into project benefits and performance analysis. There are several inputs to the program, including the following: a structure inventory containing structure value and first floor elevation, hydrologic data, and depth damage curves.

Since there have been no recent updates to the floodplain damage data of the original project study published in the "1934 Agreement," it was necessary to perform an inventory of damageable properties in the study area to produce a structure inventory. In order to obtain a count of structures in the study area, inundation mapping resulting from the HEC-RAS modeling of a PMF flood event was overlaid on USGS 7.5-minute quad sheets with ten-foot contour intervals. This provided a first estimate of the number of structures in the study area. In order to identify changes in development from that shown on the original topographic maps, aerial photography was obtained from Terra Server using an ArcView extension and overlaid on the quads. The total number of structures were counted, resulting in a structure count that is consistent with current development in the area. First floor elevations for both residential and commercial structures were estimated by first establishing ground elevation using the "spot surface' tool in Arc Map. From there, two feet was added to the ground elevation to establish the first floor elevation. Structure values for both residential and commercial structures were estimated by taking a random sample of structures from the study area and utilizing Marshall and Swift Real Estate Estimation software, which is the Corps wide accepted methodology for structure value estimation. Hydrologic data, including water surface elevations were provided by the District's Hydraulics and Hydrology Section.

As stated, depth-damage curves for residential and commercial structures were imported into the HEC-FDA program. The residential depth-damage relationships used were published in Economics Guidance Memorandum 01-03, Generic Depth-Damage Relationships (for residential structures without basements) dated 4 December 2000. The categories within the residential depth-damage functions include: one-story – no basement; one-story – with basement; two-story – no basement; two-story – with basement; and split-level with no basement. Those curves utilized for commercial structures were the "New Orleans" commercial depth damage functions. The categories within the commercial depth-damage functions include the following: eating & recreation; grocery & gas station; multi-family units (over 5); professional services; public facilities; repairs & home use; retail & personal services; and warehouses & contractors. For the purpose of this study structures labeled "commercial" included any structure which is not a residential structure (i.e. public facilities).

Flood Damage Results

As previously mentioned the District's Geotechnical section identified seven pools of concern for analysis. These pools included the following elevations: 906, 929, 936, 949, 952, 962, and 964. The specified pool elevations and their corresponding percentage of PMF and recurrence events are provided in Table 1-1.

Table 1-1 - Selected Pool Elevation by Percentage PMF and Recurrence Event

Pool Elevation	% PMF	Recurrence Interval (Year)
906	5.5%	5.5
929	8.3%	3.5
936	14.7%	64
949	16.2%	94
952	33%	210
962	36%	300
964	100%	310

The with and without project failure conditions were both analyzed using the HEC-FDA program and the results are presented below.

Base Condition Flood Damages

Pool Elevation 906

The results of FDA modeling for a 906 pool elevation event with project failure indicate that 212 structures in the study area would be inundated. Residential structures expected to be flooded total 187 and commercial total 25. Estimated flood damage associated with a 906 pool elevation event total approximately $26,424,000. Residential damage would account for 23% of total damage and commercial damage would account for 77% of total damage. This information is compiled in Table 1-9.

Table 1-2 Base Condition: 906 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	187	$6,153
Commercial	25	$20,271
Total	212	$26,424

Pool Elevation 929

The results of FDA modeling for a 929 pool elevation event with project failure indicate that 248 structures in the study area would be inundated. Residential structures expected to be flooded total 211 and commercial total 37. Estimated flood damage associated with a 929 pool elevation event total approximately $36,433,000. Residential damage would account for 18% of total damage and commercial damage would account for 82% of total damage. This information is compiled in Table 1-10.

Table 1-3 Base Condition: 929 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	211	$6,713
Commercial	37	$29,720
Total	248	$36,433

Pool Elevation 936

The results of FDA modeling for a 936 pool elevation event with project failure indicate that 288 structures in the study area would be inundated. Residential structures expected to be flooded total 240 and commercial total 48. Estimated flood damage associated with a 936 pool elevation event total approximately $63,758,000. Residential damage would account for 13% of total damage and commercial damage would account for 87% of total damage. This information is compiled in Table 1-11.

Table 1-4 Base Condition: 936 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	240	$8,514
Commercial	48	$55,244
Total	288	$63,758

Pool Elevation 949

The results of FDA modeling for a 949 pool elevation event with project failure indicate that 318 structures in the study area would be inundated. Residential structures expected to be flooded total 267 and commercial total 51. Estimated flood damage associated with a 949 pool elevation event total approximately $70,696,000. Residential damage would account for 14% of total damage and commercial damage would account for 86% of total damage. This information is compiled in Table 1-12.

Table 1-5 Base Condition: 949 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	267	$9,816
Commercial	51	$60,880
Total	318	$70,696

Pool Elevation 952

The results of FDA modeling for a 952 pool elevation event with project failure indicate that 3,010 structures in the study area would be inundated. Residential structures expected to be flooded total 2,542 and commercial total 468. Estimated flood damage associated with a 952 pool elevation event total approximately $347,367,000. Residential damage would account for 15% of total damage and commercial damage would account for 85% of total damage. This information is compiled in Table 1-13.

Table 1-6 Base Condition: 952 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	2,542	$52,105
Commercial	468	$295,262
Total	3,010	$347,367

Pool Elevation 962

The results of FDA modeling for a 962 pool elevation event with project failure indicate that 3,186 structures in the study area would be inundated. Residential structures expected to be flooded total 2,688 and commercial total 498. Estimated flood damage associated with a 962 pool elevation event total approximately $371,963,000. Residential damage would account for 15% of total damage and commercial damage would account for 85% of total damage. This information is compiled in Table 1-14.

Table 1-7 Base Condition: 962 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	2688	$55,794
Commercial	498	$316,169
Total	3186	$371,963

Pool Elevation 964

The results of FDA modeling for a 964 pool elevation event with project failure indicate that 6,335 structures in the study area would be inundated. Residential structures expected to be flooded total 5,524 and commercial total 811. Estimated flood damage associated with a 964 pool elevation event total approximately $2,019,006,000. Residential damage would account for 22% of total damage and commercial damage would account for 78% of total damage. This information is compiled in Table 1-15.

Table 1-8 Base Condition: 964 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	5,524	$444,181
Commercial	811	$1,574,825
Total	6,335	$2,019,006

With Rehab Condition Flood Damages

Pool Elevation 906

The results of FDA modeling for a 906 pool elevation event without failure indicate that 203 structures in the study area would be inundated. Residential structures expected to be flooded total 178 and commercial total 25. Estimated flood damage associated with a 906 pool elevation event total approximately $24,434,000. Residential damage would account for 25% of total damage and commercial damage would account for 75% of total damage. This information is compiled in Table 1-2.

Table 1-9 With Rehab Condition: 906 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	178	$6,034
Commercial	25	$18,400
Total	203	$24,434

Pool Elevation 929

The results of FDA modeling for a 929 pool elevation event without failure indicate that 229 structures in the study area would be inundated. Residential structures expected to be flooded total 203 and commercial total 26. Estimated flood damage associated with a 929 pool elevation event total approximately $27,927,000. Residential damage would account for 23% of total damage and commercial damage would account for 77% of total damage. This information is compiled in Table 1-3.

Table 1-10 With Rehab Condition: 929 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	203	$6,353
Commercial	26	$21,574
Total	229	$27,927

Pool Elevation 936

The results of FDA modeling for a 936 pool elevation event without failure indicate that 235 structures in the study area would be inundated. Residential structures expected to be flooded total 208 and commercial total 27. Estimated flood damage associated with a 936 pool elevation event total approximately $28,822,000. Residential damage would account for 25% of total damage and commercial damage would account for 75% of total damage. This information is compiled in Table 1-4.

Table 1-11 With Rehab Condition: 936 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	208	$7,095
Commercial	27	$21,727
Total	235	$28,822

Pool Elevation 949

The results of FDA modeling for a 949 pool elevation event without failure indicate that 253 structures in the study area would be inundated. Residential structures expected to be flooded total 219 and commercial total 34. Estimated flood damage associated with a 949 pool elevation event total approximately $31,087,000. Residential damage would account for 24% of total damage and commercial damage would account for 76% of total damage. This information is compiled in Table 1-5.

Table 1-12 With Rehab Condition: 949 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	219	$7,361
Commercial	34	$23,726
Total	253	$31,087

Pool Elevation 952

The results of FDA modeling for a 952 pool elevation event without failure indicate that 396 structures in the study area would be inundated. Residential structures expected to be flooded total 343 and commercial total 53. Estimated flood damage associated with a 952 pool elevation event total approximately $91,340,000. Residential damage would account for 14% of total damage and commercial damage would account for 86% of total damage. This information is compiled in Table 1-6.

Table 1-13 With Rehab Condition: 952 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	343	$12,982
Commercial	53	$78,358
Total	396	$91,340

Pool Elevation 962

The results of FDA modeling for a 962 pool elevation event without failure indicate that 469 structures in the study area would be inundated. Residential structures expected to be flooded total 413 and commercial total 56. Estimated flood damage associated with a 962 pool elevation event total approximately $106,508,000. Residential damage would account for 16% of total damage and commercial damage would account for 84% of total damage. This information is compiled in Table 1-7.

Table 1-14 With Rehab Condition: 962 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	413	$16,600
Commercial	56	$89,908
Total	469	$106,508

Pool Elevation 964

The results of FDA modeling for a 964 pool elevation event without failure indicate that 5050 structures in the study area would be inundated. Residential structures expected to be flooded total 4,349 and commercial total 701. Estimated flood damage associated with a 964 pool elevation event total approximately $1,547,194,000. Residential damage would account for 22% of total damage and commercial damage would account for 78% of total damage. This information is compiled in Table 1-8.

Table 1-15 With Rehab Condition: 964 Pool Elevation, Damaged Structures and Total Flood Damage by Structure Category

Damage Category	Number of Inundated Structures	Damage FY08 Price Level (x1000)
Residential	4,349	$346,440
Commercial	701	$1,200,754
Total	5,050	$1,547,194

Addendum 2: Lost Flood Protection during Repairs

Lost Flood Protection During Repairs

The authorized project purposes of Bolivar Dam are flood damage reduction and recreation, from which project benefits are derived. Annual project flood control benefits for flood damage reduction are calculated by averaging the historic annual benefits and are discussed below.

Historical Average Annual Damages Prevented

The Bolivar Dam has prevented significant flooding over the life of the project. There have been no occurrences of water entering the spillway following completion of the project in 1938. As previously mentioned Bolivar Dam is one of 14 original flood control damns within the Muskingum Basin System. Benefits within the Muskingum River System are attributed to the entire system, rather than to individual projects. Previous studies have been performed to determine an appropriate breakdown of the total Muskingum Basin System benefits on a project by project basis that would be applicable to long term averaging. These studies involved a detailed analysis of several selected Muskingum River floods in which contribution by individual projects at each evaluation center was computed. Dover is credited with 6.7% of the total benefits attributed to the Muskingum River System as reported in *Piedmont Lake, Dam Safety Assurance Evaluation Report*, dated April 1996. The percentage breakdown per project in the Muskingum River System is presented in Table 2-1. This percentage was applied to historical damages prevented to derive a benefit distribution attributable to Bolivar.

Table 2-1 – Percentage Breakdown of Muskingum River System Benefits

Project	Percent of Total Benefits
Atwood	1.9
Beach City	10.3
Bolivar	**6.7**
Charles Mill	3.7
Clendening	1.7
Dover	15.2
Leesville	1.3
Mohawk	25.0
Mohicanville	6.4
Piedmont	1.3
Pleasant Hill	4.9
Senecaville	2.7
Tappan	2.1
Wills Creek	17.0

The historic damages prevented by both the Muskingum River System and Bolivar Dam are shown in Table 2-2. Historic damages prevented are shown both at the price level of each indicated year and in FY 2008 price levels. The yearly damages prevented are averaged to arrive at a number that represents the average of the annual benefits provided by the project. This number is $ 7,104,589 in FY 2007 levels. The total flood damages prevented by the project in FY 2008 price levels[9] for years 1937-2007 are approximately $ 511,549,860. These are based on aggregated stage-damage and benefit data developed by the original study for the system. The data has been adjusted in order to make appropriate estimates where current stream gage stations are located and are indexed to current price levels each year. Observed peak stages during each flood event that are above zero damage at the gages are compared with estimates of what the natural stages would have been without the constructed project in order to estimate flood damage reduction benefits for the year.

[9] With the exception of the historical damages prevented, all other dollar figures presented in Appendix B are in 01-Oct-2007 (FY08) dollars.

Table 2-2 – Historic Damages Prevented[10]

	Muskingum River System		Bolivar Dam	
Year	Historical Damages Prevented	Damages Prevented FY 2008 Price Level	Historical Damages Prevented	Damages Prevented FY 2008 Price Level
1937	$1,834,286	$62,795,015	$122,897	$4,207,266
1938	$1,834,286	$62,528,935	$122,897	$4,189,439
1939	$1,834,286	$62,528,935	$122,897	$4,189,439
1940	$1,834,286	$60,978,630	$122,897	$4,085,568
1941	$1,834,286	$57,197,010	$122,897	$3,832,200
1942	$1,834,286	$53,466,770	$122,897	$3,582,274
1943	$1,834,286	$50,885,616	$122,897	$3,409,336
1944	$1,834,286	$49,353,942	$122,897	$3,306,714
1945	$1,834,286	$47,911,781	$122,897	$3,210,089
1946	$1,834,286	$42,649,794	$122,897	$2,857,536
1947	$1,834,286	$35,730,820	$122,897	$2,393,965
1948	$1,834,286	$32,010,474	$122,897	$2,144,702
1949	$1,834,286	$30,936,748	$122,897	$2,072,762
1950	$1,834,286	$28,934,958	$122,897	$1,938,642
1951	$1,834,286	$27,176,480	$122,897	$1,820,824
1952	$1,834,286	$25,934,672	$122,897	$1,737,623
1953	$1,834,286	$24,594,714	$122,897	$1,647,846
1954	$1,834,286	$23,498,135	$122,897	$1,574,375
1955	$1,834,286	$22,358,831	$122,897	$1,498,042
1956	$1,834,286	$21,324,897	$122,897	$1,428,768
1957	$1,834,286	$20,382,360	$122,897	$1,365,618
1958	$4,008,000	$42,482,688	$268,536	$2,846,340
1959	$14,446,000	$145,819,410	$967,882	$9,769,900
1960	$1,574,000	$15,367,512	$105,458	$1,029,623
1961	$7,531,000	$71,531,163	$504,577	$4,792,588
1962	$2,204,000	$20,333,922	$147,668	$1,362,373
1963	$19,070,000	$170,275,416	$1,277,690	$11,408,453
1964	$8,779,500	$75,460,553	$588,227	$5,055,857
1965	$8,779,500	$72,740,554	$588,227	$4,873,617

[10] Data for years 1937-1957 is estimated because complete yearly historical records were not available; however the cumulative total through 1957 of $38,520,006 was on record. The cumulative total was divided by the 21 years that the system had been in operation to yield a yearly estimate.

Table 2-2 – Historic Damages Prevented Cont'[11]

	Muskingum River System		Bolivar Dam	
Year	Historical Damages Prevented	Damages Prevented FY 2008 Price Level	Historical Damages Prevented	Damages Prevented FY 2008 Price Level
1966	$8,779,500	$69,314,109	$588,227	$4,644,045
1967	$8,779,500	$65,764,504	$588,227	$4,406,222
1968	$2,817,000	$19,621,442	$188,739	$1,314,637
1969	$3,273,000	$20,749,634	$219,291	$1,390,225
1970	$53,384,000	$310,987,893	$3,576,728	$20,836,189
1971	$10,941,000	$55,673,843	$733,047	$3,730,147
1972	$5,196,000	$23,845,876	$348,132	$1,597,674
1973	$2,780,000	$11,802,164	$186,260	$790,745
1974	$8,290,000	$33,016,361	$555,430	$2,212,096
1975	$77,522,000	$281,945,972	$5,193,974	$18,890,380
1976	$55,252,000	$185,132,170	$3,701,884	$12,403,855
1977	$48,683,000	$152,039,882	$3,261,761	$10,186,672
1978	$97,136,000	$281,505,447	$6,508,112	$18,860,865
1979	$255,384,000	$684,170,589	$17,110,728	$45,839,429
1980	$85,960,000	$213,638,616	$5,759,320	$14,313,787
1981	$58,514,000	$133,166,939	$3,920,438	$8,922,185
1982	$28,083,000	$59,066,075	$1,881,561	$3,957,427
1983	$58,564,000	$115,874,909	$3,923,788	$7,763,619
1984	$22,527,000	$43,711,943	$1,509,309	$2,928,700
1985	$57,276,000	$109,841,578	$3,837,492	$7,359,386
1986	$39,321,000	$73,652,490	$2,634,507	$4,934,717
1987	$44,358,000	$80,994,124	$2,971,986	$5,426,606
1988	$15,600,000	$27,772,073	$1,045,200	$1,860,729
1989	$43,836,000	$76,416,169	$2,937,012	$5,119,883
1990	$66,950,000	$113,823,489	$4,485,650	$7,626,174
1991	$112,601,000	$187,357,817	$7,544,267	$12,552,974
1992	$1,930,000	$3,114,714	$129,310	$208,686
1993	$60,410,000	$93,281,852	$4,047,470	$6,249,884
1994	$164,371,000	$244,520,099	$11,012,857	$16,382,847
1995	$17,145,000	$25,211,392	$1,148,715	$1,689,163
1996	$240,370,000	$344,088,372	$16,104,790	$23,053,921
1997	$54,061,000	$74,651,690	$3,622,087	$5,001,663
1998	$153,775,000	$208,972,952	$10,302,925	$14,001,188
1999	$68,298,000	$90,684,504	$4,575,966	$6,075,862

[11] Data for the individual years of 1964-1967 was also not available so the cumulative total for those years was divided by 4 to yield a yearly estimate.

Table 2-2 – Historic Damages Prevented Cont'

	Muskingum River System		Bolivar Dam	
Year	Historical Damages Prevented	Damages Prevented FY 2008 Price Level	Historical Damages Prevented	Damages Prevented FY 2008 Price Level
2000	$25,943,000	$33,549,499	$1,738,181	$2,247,816
2001	$26,325,000	$33,388,716	$1,763,775	$2,237,044
2002	$17,614,000	$21,674,003	$1,180,138	$1,452,158
2003	$29,815,000	$35,832,339	$1,997,605	$2,400,767
2004	$478,489,000	$541,032,186	$32,058,763	$36,249,156
2005	$609,288,000	$658,302,707	$40,822,296	$44,106,281
2006	$10,121,000	$10,328,992	$678,107	$692,042
2007	$222,319,000	$222,319,000	$14,895,373	$14,895,373
Average	**$50,098,493**	**$106,042,674**	**$3,356,599**	**$7,104,859**
Sum Total	**$3,556,993,000**	**$7,529,029,857**	**$238,318,531**	**$511,549,860**

Lost Flood Protection During Repairs

Estimates of lost flood protecting during repairs in the case of unsatisfactory performance are based on the historic average annual damages. As previously stated the historic average annual flood damages prevented by Bolivar Dam are $7,104,859 yearly. The District's geotechnical section provided estimates of time of repair for the various performance levels considered under this study. The pools, their time of repair and the associated economic consequences are displayed below in Table 2-3.

Table 2-3 – Lost Flood Protection During Repairs

Pool Elevation	Time of Repair	Lost Flood Protection
906	6 months	$3,552,430
929	6 months	$3,552,430
936	6 months	$3,552,430
949	12 months	$7,104,859
952	12 months	$7,104,859
962	12 months	$7,104,859
964	18 months	$10,657,289

Addendum 3: Recreation Benefits Foregone during Repairs

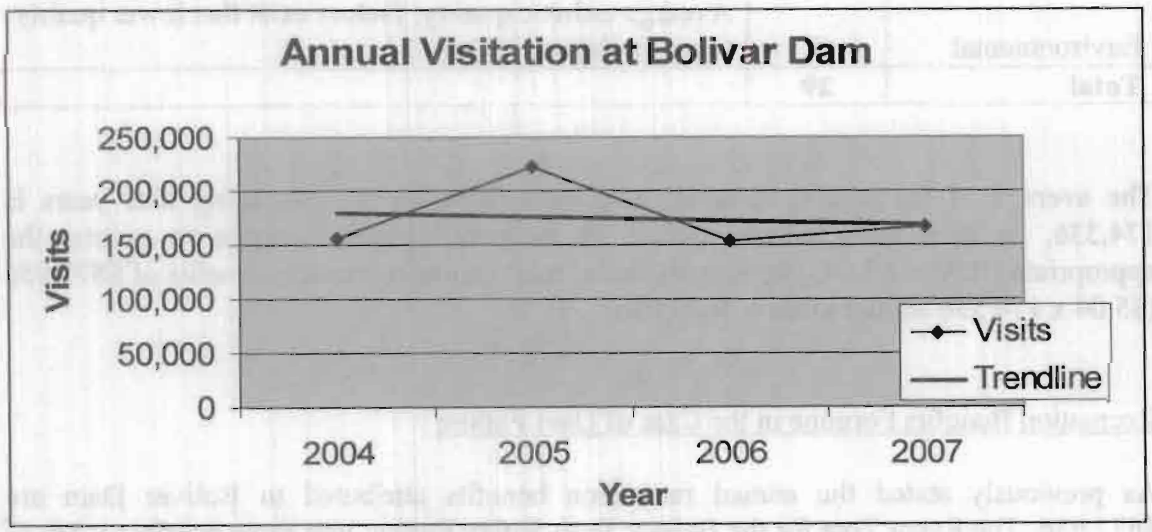
Calculation of Recreation Benefits at Bolivar Dam

Recreation opportunities at the Bolivar Dam site consist of day use facilities set up primarily for picnicking and fishing, limited hunting and trapping, and an equestrian trail. While there are no marked hiking trails on the grounds, hiking is permitted on the horse trails and in the surrounding woodland. Annual visitation data for the project was obtained from the Operations and Maintenance Business Information Link (OMBIL) system for the past 4 years[12], from 2004 to date. Average annual visitation at Bolivar Dam totals 174,336 visits and is presented in Table 3-1. The historic annual visitation and the resulting trend line are presented graphically in Figure 3-1.

Table 3-1 - Recent Historic Visitation

	Fiscal Year	Visitor Hours		Visits
	2004		469,249	156,419
	2005		664,672	221,559
	2006		459,742	153,246
	2007		498,362	166,120
Average			523,006	174,336

Figure 3-1 - Recent Historic Visitation



[12] The OMBIL system was unable to provide data prior to 2004.

The Unit Day Value (UDV) methodology established in ER 1105-2-100, Appendix E, Section VII was employed as a proxy for willingness to pay in order to estimate the current recreation benefits of Bolivar Dam. The UDV method employs a set of five criteria (recreation experience, availability of opportunity, carrying capacity, accessibility and environment) upon which the project site is evaluated and assigned points. The point total is then multiplied by the associated UDV in order to convert the assigned points to a dollar value representing estimated recreation benefits. The UDVs are established in Economic Guidance Memorandum, 08-02, Unit Day Values for Recreation, Fiscal Year 2008 (EGM-08-02) dated 19 October 2007. The point assignments for each recreation component were developed by the project design team's economist and environmental planner and are presented in Table 3-2.

Table 3-2 – Bolivar Point Assignments to Determine Recreation Benefit

Unit Day Method		
Criteria	Points	Judgment Factors
Recreation Experience	7	There are several general activities
Availability of Opportunity	3	Several within 1 hour travel time; a few within 30 minutes travel time.
Carrying Capacity	3	Basic facility to conduct activity(ies)
Accessibility	11	Fair access, fair road to site; fair roads within site.
Environmental	5	Average esthetic quality; factors exist that lower quality to minor degree
Total	**29**	

The average of the annual visitation to Dover Dam for the preceding four years is 174,336, as previously stated. With 29 estimated general recreation points, the appropriate UDV is $5.04, yielding estimated total annual recreation benefits of $877,956 ($5.04 x 174,336 annual visits = $877,956).

Recreation Benefits Forgone in the Case of Dam Failure

As previously stated the annual recreation benefits attributed to Bolivar Dam are $877,956. The Event Tree for the Bolivar Dam Safety Project lists three possible types of failure – minor, major and catastrophic. Consultation with the project design team resulted in the conclusion that a minor failure would result in a 10% loss of project recreation benefits over a six month time period. Consequences stemming from a major failure of the project are expected to be a 50% loss of project recreation benefits over an 18 month period of time. Finally, it is believed that a catastrophic failure of the dam would result in a 75% loss of project recreation benefits over a twenty four month period of time.

Projected impacts to recreation benefits given the type of failure realized is presented in Table 3-3.

Table 3-3 – Impacts to Expected Recreation Benefits in Case of Failure

	Benefits with Failure	Benefits Without Failure	Benefits Foregone
Minor Failure	$395,080	$438,978	$43,898
Major Failure	$658,467	$1,316,934	$658,467
Catastrophic Failure	$438,978	$1,755,912	$1,316,934

Addendum 4: Bolivar Event Trees

Event Tree for Bolivar Base Condition with Consequences

Pool Elevation Probability	Probability of Unsatisfactory Performance	Performance Level Probability	Branch Probability	Consequences ($)		Notes	Calculations
El. 924 50.00%	Pr(u) (Unsatisfactory Perf.) 0.00036%	Impacts w/o Failure 99.00%	0.00018%	Flood Damages (increased releases)	$633,000.00		
				Repair Costs + Increased monitoring/study/surveillance	$350,000.00		
				Forgone FDR Benefits	$3,552,429.50	For 6 Months of Repair	$7,104,859 Annual Benefits * 0.5 years
				Recreation Losses	$438,978.00	For 6 Months of Repair	$877,956 Annual Benefits * 0.5 years
		Failure 1.00%	0.00000%	Flood Damages	$26,424,000.00		
				Repair Costs	$33,187,000.00	**Costs would incur over 2 years	
				Forgone FDR Benefits (Historic Avr. Annual Benefits)	$14,209,718.00	For 2 years during Failure Repair	$7,104,859 Annual Benefits * 2 years
				Recreation Losses	$1,755,912.00	For 2 years during Failure Repair	$877,956 Annual Benefits * 2 years
	Reliability (Satisfactory Performance) 99.99964%		49.99982%				
El. 929 28.57%	Pr(u) (Unsatisfactory Perf.) 0.76870%	Impacts w/o Failure 95.00%	0.20864%	Flood Damages (increased releases)	$1,852,000.00		
				Repair Costs + Increased monitoring/study/surveillance	$350,000.00		
				Lost FDR Benefits (Historic Avr. Annual Benefits)	$3,552,429.50	6 Months of Repair	$7,104,859 Annual Benefits * 0.5 years
				Recreation Losses	$438,978.00	6 Months of Repair	$877,956 Annual Benefits * 0.5 years
		Failure 5.000%	0.01098%	Flood Damages	$36,433,000.00		
				Repair Costs	$33,187,000.00	**Costs would incur over 2 years	
				Forgone FDR Benefits (Historic Avr. Annual Benefits)	$14,209,718.00	For 2 years during Failure Repair	$7,104,859 Annual Benefits * 2 years
				Recreation Losses	$1,755,912.00	For 2 years during Failure Repair	$877,956 Annual Benefits * 2 years
	Reliability (Satisfactory Performance) 99.23130%		28.35038%				
El. 936 1.56%	Pr(u) (Unsatisfactory Perf.) 96.65560%	Impacts w/o Failure 90.00%	1.35704%	Flood Damages (increased releases)	$6,188,000.00		
				Repair Costs + Increased monitoring/study/surveillance	$1,600,000.00		
				Lost FDR Benefits (Historic Avr. Annual Benefits)	$7,104,859.00	12 Months of Repair	
				Recreation Losses	$877,956.00	12 Months of Repair	
		Failure 10.000%	0.15078%	Flood Damages (Breach)	$83,758,000.00		
				Repair Costs	$33,187,000.00	**Costs would incur over 2 years	
				Lost FJH Benefits (Historic Avr. Annual Benefits)	$14,209,718.00	For 2 years during Failure Repair	$7,104,859 Annual Benefits * 2 years
				Recreation Losses	$1,755,912.00	For 2 years during Failure Repair	$877,956 Annual Benefits * 2 years
	Reliability (Satisfactory Performance) 3.34440%		0.05217%				
El. 949 1.06%	Pr(u) (Unsatisfactory Perf.) 97.18879%	Impacts w/o Failure 70.00%	0.72114%	Flood Damages (increased releases)	$6,715,000.00		
				Repair Costs + Increased monitoring/study/surveillance	$1,600,000.00		
				Forgone FDR Benefits (Historic Avr. Annual Benefits)	$7,104,859.00	12 Months of Repair	
				Recreation Losses	$877,956.00	12 Months of Repair	
		Failure 30.000%	0.30906%	Flood Damages (Breach)	$70,888,000.00		
				Repair Costs	$33,187,000.00	**Costs would incur over 2 years	
				Lost FDR Benefits (Historic Avr. Annual Benefits)	$14,209,718.00	For 2 years during Failure Repair	$7,104,859 Annual Benefits * 2 years
				Recreation Losses	$1,755,912.00	For 2 years during Failure Repair	$877,956 Annual Benefits * 2 years
	Reliability (Satisfactory Performance) 2.81121%		0.02980%				
El. 952 0.48%	Pr(u) (Unsatisfactory Perf.) 98.00402%	Impacts w/o Failure 40.00%	0.18817%	Flood Damages (increased releases)	$0.00		
				Repair Costs + Increased monitoring/study/surveillance	$6,500,000.00		
				Forgone FDR Benefits (Historic Avr. Annual Benefits)	$7,104,859.00	12 Months of Repair	
				Recreation Losses	$877,956.00	12 Months of Repair	
		Failure 60.000%	0.28225%	Flood Damages (Breach)	$547,387,000.00		
				Repair Costs	$33,187,000.00	**Costs would incur over 2 years	
				Lost FDR Benefits (Historic Avr. Annual Benefits)	$14,209,718.00	For 2 years during Failure Repair	$7,104,859 Annual Benefits * 2 years
				Recreation Losses	$1,755,912.00	For 2 years during Failure Repair	$877,956 Annual Benefits * 2 years
	Reliability (Satisfactory Performance) 1.99598%		0.00958%				
El. 962 0.33%	Pr(u) (Unsatisfactory Perf.) 99.53689%	Impacts w/o Failure 40.00%	0.13139%	Flood Damages (increased releases)	$0.00		
				Repair Costs + Increased monitoring/study/surveillance	$6,500,000.00		
				Forgone FDR Benefits (Historic Avr. Annual Benefits)	$7,104,859.00	12 Months of Repair	
				Recreation Losses	$877,956.00	12 Months of Repair	
		Failure 60.000%	0.19708%	Flood Damages (Breach)	$371,963,000.00		
				Repair Costs	$33,187,000.00	**Costs would incur over 2 years	
				Lost FDR Benefits (Historic Avr. Annual Benefits)	$14,209,718.00	For 2 years during Failure Repair	$7,104,859 Annual Benefits * 2 years
				Recreation Losses	$1,755,912.00	For 2 years during Failure Repair	$877,956 Annual Benefits * 2 years
	Reliability (Satisfactory Performance) 0.46311%		0.00153%				
El. 964 0.01%	Pr(u) (Unsatisfactory Perf.) 100.00%	Impacts w/o Failure 25.00%	0.00250%	Flood Damages (increased releases)	$0.00		
				Repair Costs + Increased monitoring/study/surveillance	$13,500,000.00		
				Forgone FDR Benefits (Historic Avr. Annual Benefits)	$10,657,288.50	18 Months of Repair	$7,104,859 Annual Benefits * 1.5 years
				Recreation Losses	$1,316,934.00	18 Months of Repair	$877,956 Annual Benefits * 1.5 years
		Failure 75.000%	0.00750%	Flood Damages (Breach)	$2,019,006,000.00		
				Repair Costs	$33,187,000.00	**Costs would incur over 2 years	
				Lost FDR Benefits (Historic Avr. Annual Benefits)	$14,209,718.00	For 2 years during Failure Repair	$7,104,859 Annual Benefits * 2 years
				Recreation Losses	$1,755,912.00	For 2 years during Failure Repair	$877,956 Annual Benefits * 2 years
	Reliability (Satisfactory Performance) 0.00%		0.00000%				

Addendum 5: Incremental Benefits

1. General: The model was programmed to attribute all disbenefits attributable to failure of both the main embankment and left abutment to only the main embankment. It was necessary to compute these joint disbenefits for the incremental analysis. The procedure and reallocation are presented in this addendum.

2. Procedure: The model was modified to print the number of failures per cycle when only the main embankment performed in an unsatisfactory manner, only the basis did so, and when both the main embankment and left abutment performed in an unsatisfactory manner during the same high water event. The results are summarized in Table A. The benefits of avoiding simultaneous failures were attributed to the main embankment, which must be subtracted for purposes of the incremental analysis since these benefits would not be realized if the left abutment was not rehabilitated. The joint benefits accounts for 2.1 percent of the main embankment's benefits

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$$(1.000 - (7.252 / (7.252 + .158))) = 2.1\%$$

Table 5-1 – Numbers and Percents of Failures

Item	Value
Main embankment only number per life cycle	7.252
Basin only number per life cycle	0.222
Both simultaneously per life cycle	0.158
Main embankment and both subtotal	7.410
Main embankment only as percent	0.979
Joint to share	0.021
Main embankment share of joint	1.000
Basin share of joint	1.000
Main embankment weighted share of joint	0.021
Basin weighted share of joint	0.021

3. Adjustments: The only adjustment necessary was to reduce the benefits for rehabilitating only the main embankment to eliminate the joint benefits that would only be realized if both components were replaced. No adjustment to the left abutment benefits was necessary since these do not include the joint benefits. The adjustment was made by applying the 2.1 percent to the dam benefits to compute the joint benefits of $208, and subtracting this amount from the total, as shown in Table B.

Table 5-2 – Incremental Benefits for Main Embankment Rehabilitation Only

Main Embankment only and joint benefits	9,760
Percent joint benefits	0.021
Amount joint benefits (0.021 x 9,760)	208
Main Embankment only benefits (9,760 – 208)	9,553

Addendum 6: Other Considerations

Loss of Life

A major reason for improving the safety of Bolivar Dam is to avoid the loss of life that would likely occur from a dam failure. The analyses explained in the following sections indicate that there is a potential threatened population for particular Bolivar Dam failure scenarios. Using inundation maps and the downstream flow profiles, population at risk (PAR) is estimated for various flood zones (depth of flooding) in each downstream reach. PAR, defined as those persons that would be exposed to injury by floodwater if they took no measures to evacuate, includes permanent and transient population. PAR may be adjusted by considering the season of year and time of day that a dam failure may occur to estimate the probable population at risk. The effectiveness of warnings and evacuation procedures are considered when estimating the loss of life. Key factors in these analyses are the water surface profiles and travel times located in Appendix J.

Determination of the Population at Risk (PAR)

The determination of population at risk (PAR) is defined as those people who would be exposed to injury by floodwater if they took no measures to evacuate. PAR includes people who reside, work, or conduct other activities in the area that would be flooded in the event of a dam breach. The Bolivar PAR was determined as part of the Dam Safety Assurance Project in 1986. The PAR was derived using U.S. Census Bureau block population and housing data for the reaches in the impact area. Inundation mapping was used to outline the flooded area for each breach condition. The total population in the inundation areas for each breach condition was recorded.

Probabilities that the flood event occurs in a particular season and time of day can be used to derive the probable PAR estimates. However, the total resident population in the study area is not expected to be likely to fluctuate significantly with the seasons. For this analysis, it was assumed that a dam breach event has an equal probability of occurring during any given time of year. Moreover, some people who live outside the floodplain work in the floodplain. It is assumed that capturing these floodplain occupancy shifts would result in no significant change to the population at risk. Thus, for the purposes of this analysis, PAR is based on census based estimates of residential population in the inundated area regardless of season or time of day.

Determination of Loss of Life (LOL)

Determination of the loss of life is based on the total population at risk, warning time, and evacuation. In the ideal situation, the total PAR would receive a warning with sufficient time to evacuate the flooded area and thus there would be no loss of life. However, with a major rain event in the area, the effectiveness of communication, warning systems, and evacuation plans could be severely hampered and there would be a high risk for loss of life, particularly in the areas just below Bolivar Dam. Additionally, in rural areas where the population is widely scattered, it is not possible that every single person would receive a warning. Additionally, some would not heed the warning and would choose to remain in the flood-prone area. Even with adequate warning, loss of life could occur among the population.

The Bureau of Reclamation (BOR) published guidance entitled "A Procedure for Estimating Loss of Life Caused by Dam Failure," DSO-99-06, September 1999. The BOR methodology is based on flood severity, amount of warning time, and the understanding of the severity of the flood. This methodology was used in estimating loss of life for this study. Table 7 in the BOR guidance document was used to estimate loss of life percentages. Professional judgment, supported by hydraulic information of velocity and computed water surface elevation, was used in describing each reach for each failure scenario analyzed (60% and 100% PMF). Table 7 from the BOR guidance is shown below.

Figure 6 -1 – Estimating Loss of Life Percentages

Flood Severity	Warning Time (minutes)	Flood Severity Understanding	Fatality Rate (Fraction of people at risk expected to die)	
			Suggested	Suggested Range
HIGH	no warning	not applicable	0.75	0.30 to 1.00
	15 to 60	vague	Use the values shown above and apply to the number of people who remain in the dam failure floodplain after warnings are issued. No guidance is provided on how many people will remain in the floodplain.	
		precise		
	more than 60	vague		
		precise		
MEDIUM	no warning	not applicable	0.15	0.03 to 0.35
	15 to 60	vague	0.04	0.01 to 0.08
		precise	0.02	0.005 to 0.04
	more than 60	vague	0.03	0.005 to 0.06
		precise	0.01	0.002 to 0.02
LOW	no warning	not applicable	0.01	0.0 to 0.02
	15 to 60	vague	0.007	0.0 to 0.015
		precise	0.002	0.0 to 0.004
	more than 60	vague	0.0003	0.0 to 0.0006
		precise	0.0002	0.0 to 0.0004

BOR guidance identifies the following categories of flood severity: Low, Medium and High. According to the BOR guidance, "Low severity occurs when no buildings are washed off their foundations. Medium severity occurs when homes are destroyed but trees or mangled homes remain for people to seek refuge in or on. High severity occurs when the flood sweeps the area clean and nothing remains." Estimates of flood severity were made for each condition, for each reach in the study area.

Warning Time and Understanding of Flood Severity.

According to the BOR guidance, "Adequate warning means officials or the media begin warning in the particular area more than 60 minutes before flood water arrives." For all failure conditions and all reaches, adequate warning was assumed (>60 minutes). Due to close monitoring of the dam during extreme flood events such as these and environmental clues, such as long periods of rainfall and rising floodwaters, ample warning time would be expected.

Another factor that has an impact on the fatality rate is the understanding of flood Severity. BOR guidance provides two categories of flood understanding Vague and Precise. According to the BOR guidance, "Vague Understanding of Flood Severity" means that the warning issuers have not yet seen an actual dam failure or do not comprehend the true magnitude of the flooding. "Precise Understanding of Flood Severity" means that the warning issuers have an excellent understanding of the flooding due to observations of the flooding made by themselves or others." It is assumed that the reach closest to the dam will have the least likelihood of precise and accurate understanding. A warning of a potential flood may be difficult to describe. Therefore, recipients of the earliest warnings may not obtain an accurate understanding of the flooding about to occur. It is assumed that the reach farthest from the dam will have the greater likelihood of precise and accurate understanding. People upstream have seen the damage potential, and any warnings have been updated to reflect more accurate information of the actual danger.

For the Bolivar analysis, a vague understanding was assumed for reach 1 and 2. The remaining reaches from Gnadenhutten to the confluence of the Muskingum in Marietta, OH would have a precise understanding and substantially more warning time. The PAR in these areas were not calculated, therefore these reaches do not contribute to the loss of life estimates for Bolivar. The table below summarizes the assumptions made in the Bolivar analysis.

Table 6-1 – Flood Designation by Condition with Associated Fatality Rate

		100% PMF With Failure	100% PMF Without Failure	60% PMF With Failure	60% PMF Without Failure
Reach 1	Flood Severity	Medium	Low	Medium	Low
	Warning Time	15 to 60	>60	15 to 60	>60
	Understanding	Vague	Vague	Vague	Vague
	Fatality Rate BOR	0.04	0.0003	0.04	0.0003
Reach 2	Flood Severity	Medium	Low	Medium	Low
	Warning Time	>60 min	>60 min	>60 min	>60 min
	Understanding	Vague	Precise	Vague	Precise
	Fatality Rate BOR	0.03	0.0002	0.03	0.0002

The loss of life calculation was determined by applying the fatality rates assumed for the with and without failure condition for each flood scenario (60 or 100% PMF) to the incremental PAR. The incremental PAR, which is the population at risk resulting from dam failure, was obtained from the previous DSA study for Bolivar. The table below summarizes these calculations.

Figure 6-2 – Travel Time and Corresponding Loss of Life per Population Center

Flood Condition	Distance From Dam (Miles)	Average Arrival *Time (Hours)	Incremental Persons-at-Risk	Fatality Rate w/Fail	Loss of Life with Failure	Fatality Rate w/o Fail	Loss of Life w/o Failure
60% PMF							
Reach 1, Bolivar Dam - Dover Dam	0.4-9.7	3.5	432	0.03	12.96	0.0003	0
Reach 2, Dover Dam - Gnadenhutten	9.8-35.5	10.5	3,559	0.03	106.77	0.0002	1
Total			**3,991**		**120**		**1**
100% PMF							
Reach 1Bolivar Dam - Dover Dam	0.4-9.7	3	54	0.03	1.62	0.0003	0
Reach 2, Dover Dam - Gnadenhutten	9.8-35.5	9	4,088	0.03	122.64	0.0002	1
Total			**4,142**		**124**		**1**

Addendum 7: Road Damages

To establish the number of miles of paved roads within the study area shape files of the road networks within the basin were obtained from the Tuscarawas County GIS website. This was imported into ARC GIS and overlain on inundation mapping of a PMF dam failure of Bolivar dam, which defines the economic study area. From this information it was estimated that approximately 500 miles of paved roads are located within the study area.

An estimate for paving an average 2-lane road where minimal preparation is required was developed for this analysis by the Federal Highway Department and Nashville District's Cost Estimating Branch[13]. Estimates were \$1 million and \$2.25 million per mile of paving respectively. The District chose to use a conservative average of \$1.5 million per mile of paving required.

<u>Base Condition Road Damages</u>

An in-depth flow/pavement analysis was not possible, but through interviews with the District's H&H staff it was concluded that it would be a conservative estimate to assume that at least 350 miles of pavement would need replacement in the case of dam failure under PMF circumstances.

The number of miles of roads that would be inundated from various pool elevations was determined by viewing GIS maps of the areas affected, looking at the density of the road network involved and estimating what percent of the total road network affected was in each of the geographical areas by pool elevation. The percent of total road network affected by pool elevation seemed to be highly correlated to the number of residential and commercial structures identified in these inundated areas. Consequently, the percentage of total miles of roads affected that would potentially need repairs by pool elevation was placed as the same percentage as residential and commercial structures by pool elevation as a percent of total residential and commercial structures at pool elevation 964. Road damages by pool level are reported in Table 7-1.

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[13] The road damages estimation methodology was the same as used in the preparation of the Wolf Creek Dam Seepage Control Major Rehabilitation Evaluation Report, dated July 11, 2005.

Table 7-1 – Road Damages by Pool Elevation – With Failure (x1000)

Pool Elevation	Miles of Roads	Damages
906	11.73	$17,588
929	13.69	$20,528
936	15.93	$23,888
949	17.57	$26,355
952	166.29	$249,428
962	176.02	$264,023
964	350.00	$525,000

With Rehab Condition Road

It is reasonable to expect damages to paved roads in scenarios that do not involve project failure. For the purposes of this study the percent of structure damages without failure and applying that same percentage to the road damages with failure to derive road damages without failure. Road damages by pool level are reported in Table 7-2.

Table 7-2 – Rehab Condition Road Damages by Pool Elevation (x1000)

Pool Elevation	Miles of Roads	Damages
906	0.28	$422
929	0.70	$1,043
936	1.55	$2,322
949	1.67	$2,504
952	166.29	$249,428
962	176.02	$264,023
964	350.00	$525,000